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2.	Patent application number *(The Patent Office will fill in this part)*	09 SEP 1999 **9921363.9**
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	University of Surrey Guildford Surrey GU2 5XH
	Patents ADP number *(if you know it)*	7985120001
	If the applicant is a corporate body, give the country/state of its incorporation	UK
4.	Title of the invention	Adaptive Multifilar Antenna
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Mathisen, Macara & Co The Coach House 6-8 Swakeleys Road Ickenham, Uxbridge, UB10 8BZ, UK
	Patents ADP number *(if you know it)*	1073001
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8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

DUPLICATE

UK PATENT APPLICATION

APPLICANTS: UNIVERSITY OF SURREY

SHORT TITLE: ADAPTIVE ANTENNA II

FORMAL TITLE: ADAPTIVE MULTIFILAR ANTENNA

APPLICATION NO:

FILED:

PRIORITY CLAIMED: Nil

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Agents for the Applicants

use terrestrial base stations and another may use orbiting satellites. This means that if the handset antenna is typically used in a vertical position (with the handset held next to the user's head) then for one service the antenna should have a radiation pattern substantially omnidirectional in azimuth and for the other service it should have an approximately hemispherical radiation pattern.

To cater for the different pattern and frequencies in use, it has been proposed to employ at least two distinct antennas within a common volute.

In a first aspect, the invention provides an adaptive multifilar antenna comprising:

n spaced filaments, where n is an integer greater than 1;

at least one filament group having a predetermined plurality of the filaments coupled together in a fixed phase relationship;

a weighting circuit operable to apply phase adjustments to signals passed to and/or from the n filaments and/or filament group;

detecting means operable to detect at least one electrical property of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of

switch means associated with each filament for selectively altering the electrical length and/or interconnections of the filaments;

means for detecting electrical properties of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and

control means, responsive to the detecting means, for controlling the operation of the matching circuit, the phasing circuit and the switch means to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.

In the invention, the phase and/or gain relationships for signals from individual filaments of a multifilar antenna, and optionally also with the electrical length and/or interconnection pattern of the filaments, can be varied automatically in order to improve (or possibly to optimise, within the resolution of the adjustment system) the properties of the antenna for a particular signal to be received or transmitted. The automatic variation may be applied identically to predetermined groups of individual filaments.

For example, in embodiments of the invention, at least one of the above parameters could be varied to provide the best received signal level, the best signal to noise ratio,

Figure 5 is an enlarged view of an alternative for the portion of Figure 3 enclosed in dotted lines;

Figure 6 is an enlarged view of an alternative for the portion of Figure 4 enclosed in dotted lines; and

Figure 7 is a plot comparing the diversity performance of differently configured QHAs.

With reference to Figure 1, a QHA comprises four helical elements 10..40 and eight radial elements 50..120. (In other embodiments six, for example, angularly spaced helical elements could be used). It will also be noted that not all the radial elements 50..120 will be present in all antenna configurations.

The helical elements are intertwined as shown in Figure 1, and are disposed about a longitudinal axis of the antenna by 90° with respect to one another. Four of the radials 50..80 are disposed on the top and four 90..120 on the bottom of the volute, connecting the helical elements and forming two bifilar loops. The antenna is fed on one set of radials 90,110 with 90° phase difference between the two feeds.

The radials 50..80 at the top end of the antenna with respect to the feeds (which in this

In other embodiments, the multifilar antenna arrangement can also be used for diversity purposes. The different filaments can be used to provide space diversity between generally uncorrelated received signals. The effect of weighting the gain and/or phase can affect both the shape and the polarisation of the radiation pattern. This effect can benefit the transceiver in two ways. Firstly, the pattern shape and the polarisation are matching the direction and the polarisation of the incoming signal to try to optimise or improve the criterion ratio (S/N or S/(N+I), and secondly the structure can be used for polarisation diversity using the resulting pattern of different filaments or pairs of filaments.

Figure 1 shows an antenna which has a generally cylindrical volute (i.e. circular in plan). Other volute shapes such as those having elliptical or rectangular plans or a truncated cone shape are also suitable for use in the present invention.

Figure 2 is a schematic diagram of an antenna system comprising an adapted QHA 200 and an antenna interface circuit.

In Figure 2, the four elements of the QHA 200 are connected separately to an adaptive matching circuit 210. (In the configuration shown in Figure 2, the antenna is in a receive mode, but it will be clear that signals could instead be supplied to the antenna, in a transmit mode, by reversing the direction of signal propagation arrows in Figure

signal, which is then passed to the demodulator 260. The information is also used to adjust the antenna system to receive the next incoming signal.

In each element of the QHA, there is a switch 290 capable of isolating a portion of the element remote from the feed point. The switch could be, for example, a PIN diode switch. Similarly, a switch 300 is capable of shorting or isolating pairs of the elements at the end remote from the feed point.

The operations performed by the switches 290 and 300, under the control of a switch controller 310, can change the response and radiation pattern of the antenna. In particular, by isolating a section of each element, the electrical length of the elements is made shorter and so the frequency of operation will be higher. Again, these operations are carried out under the control of the system controller to improve or possibly optimise operation with a particular signal frequency, polarisation and direction of propagation.

Alternatively, or additionally, the antenna element may be caused to have several resonant modes by the inclusion of one or more antenna traps. This causes the antenna to be resonant (and therefore have increased gain) at more than one operating frequency.

A VSWR detector 460 operates in a transmit and/or receive mode to detect the standing wave ratio of the antennas. The output of this is stored in the RAM 440.

The RAM is connected to a digital signal processing (DSP) unit 470 which combines the digital representations of the signals stored in the RAM 440 in respective proportions and using respective phases (i.e. performs the operation of the weighting blocks W1..W4), detects and optimises the selected parameter such as signal-to-noise ratio, sends control signals to the adaptive matching circuits to change from one frequency band to another or to overcome de-tuning effects, and also controls the switch controller 310 and in turn the switches 290,300 within the helical elements.

One appropriate DSP algorithm is for the transmitter to send packet header, reference or training symbols, which are known to the receiver. Any disturbance to the received signals during the reception of the training symbols is a measure of N+I and can be reduced by trial and error (repeated combining of the digital representations stored in the RAM 440), direct matrix inversion of the associated correlation matrix or by iteration approaches such as so-called LMS or RLS algorithms. However, even if known training symbols are not available, a measure of the disturbance to the signal can be made by error detection algorithms applied to the received symbols.

Figure 4 is a more detailed schematic diagram of an alternative implementation of the

The output of the combiner 240' is fed into a single quadrature downconverter 400'. Thus, unlike the implementation shown in Figure 3, only one downconverter 400' is required. Similarly, only one quadrature modulator 450' is required.

This alternative implementation has two main advantages. Firstly, since only one downconverter 400' and one modulator 450' is required, there is a resultant cost saving in the manufacture of the transceiver.

Secondly, since most of the noise in the received signal is introduced by the receiver, there is a fourfold decrease in the noise added by the receiver section since the signal passes through only one (instead of four) downconverters 400'. As a further subsidiary advantage, since the signal from all four antenna elements is subjected to the same noise in the single downconverter 400', it is not necessary to apply gain weightings. Thus the weighting circuits W1,W2,W3,W4 may be arranged only to apply phase adjustments to the signals received by the antenna elements. This simplifies their construction and therefore also has cost and reliability advantages.

In order to optimise the weightings, a slightly different approach may be taken to that used with the implementation of Figure 3. It will be noted that in the implementation of Figure 3, the stored data may be iteratively processed with different weighting applied to the data until an optimal or at least improved result is obtained. However,

elements. The figures have been derived from complex coefficients produced empirically. It will be noted that in the table below, the diametrically opposite pairs of elements have correlation coefficients in excess of 0.7.

Table 1 : Diversity parameters for four elements of the QHA

Correlation coefficient matrix	Element 10	Element 20	Element 30	Element 40
Element 10	1.00	0.13	0.75	0.14
Element 20	0.13	1.00	0.17	0.76
Element 30	0.75	0.17	1.00	0.20
Element 40	0.14	0.76	0.20	1.00

Thus, although the grouping of elements is described below in connection with two pairs of elements, on a more general level, the predetermined groups of elements may be groups of elements which are each correlated to within 0.6, preferably 0.7 and more preferably 0.8 or better.

For the quadrifilar helical antenna described below, the pairs of elements are coupled in pairs with a 180° phase shift. This may be achieved using fixed combiners or baluns B1, B2 as shown in Figures 5 and 6.

Looking particularly at Figure 5, it will be noted that the components shown in that Figure can be used to replace the components shown within the dotted outline on

transceiver and the antenna).

Thus it will be seen that the optimal solution will usually be separate control of each element 10..40. However, a very satisfactory compromise may be reached between cost and performance by carefully selecting elements (for example according to their diversity correlation coefficient, however measured) and combining these elements with suitable fixed phase shifts to provide a reduced number of antenna feeds.

apply gain adjustments to signals passed to and/or from the filaments and/or filament group.

3. An antenna according to claim 1 or claim 2, wherein the control means is operable to control the operation of the matching circuit to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.

4. An antenna according to any preceding claim, including switch means associated with a plurality of the filaments for selectively altering the electrical length and/or interconnections of the filaments and the signal connections to/from the filaments being at a first end of each filament; and

the switch means being operable to selectively interconnect pairs of filaments a second end of those filaments being remote from the first end.

5. An antenna according to any preceding claim, including switchable filaments having switch means for selectively altering the electrical length and/or interconnections of the switchable filaments and

each of the switchable filaments including at least a first filament section and a second filament section; and

8. An antenna according to any one of the preceding claims, in which:

the detecting means is operable to detect a signal level of a received signal; and

the control means is operable to control the operation of the matching circuit and/or the weighting circuit so as to improve the signal level of the received signal.

9. An antenna according to any one of the preceding claims, in which:

the detecting means is operable to detect a VSWR for a transmitted signal; and

the control means is operable to control the operation of the matching circuit and/or the weighting circuit so as to improve the VSWR for transmission of that signal.

10. An antenna according to any one of the preceding claims, in which the detecting means comprises:

analogue to digital conversion means for converting respective signals received by the filaments and/or filament group into corresponding digital representations

a memory for storing the digital representations;

to combine the respective signals using respective gain weighting.

13. An antenna according to any one of the preceding claims, in which the detecting means operates at least during reception of a reference signal burst by the antenna.

14. An antenna according to any one of the preceding claims, in which n is an even integer.

15. An antenna according to any one of the preceding claims, in which n is equal to 4 or 6.

16. An antenna according to any preceding claim, wherein n is 4 and including two filament groups each of two diametrically opposed filaments, the filaments in each respective group being coupled together with a phase weighting of substantially 180°.

17. An antenna according to any preceding claim wherein the filaments in the or each filament group have a diversity correlation of 0.7 or better.

18. An antenna according to any one of the preceding claims, in which the filaments are helically shaped.

n spaced antenna filaments, where n is an integer greater than 1;

at least one filament group having a predetermined plurality of the filaments coupled together in a fixed phase relationship;

a matching circuit for matching the characteristic impedance of the antenna to that of a transmitting and/or receiving apparatus;

a phasing circuit for applying respective gain and phase adjustments to signals passed to and/or from the n filaments and/or filament group;

switch means associated with each filament for selectively altering the electrical length and/or interconnections of the filaments;

means for detecting electrical properties of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and

control means, responsive to the detecting means, for controlling the operation of the matching circuit, the phasing circuit and the switch means to adjust the properties of the multifilar antenna to suit better a current signal to be received or transmitted.

ABSTRACT

ADAPTIVE MULTIFILAR ANTENNA

A multifilar antenna (200) comprises n spaced antenna filaments, where n is an integer greater than 1; a matching circuit (210) for matching the characteristic impedance of the antenna to that of a transmitting and/or receiving apparatus; a weighting circuit (240) for applying gain and phase adjustments to signals passed to or from the n filaments; switch means (310) associated with at least some of the filaments for selectively altering the electrical length and/or interconnections of the filaments; means for detecting electrical properties of the multifilar antenna with respect to the frequency, polarisation and/or direction of propagation of a signal to be received or transmitted by the multifilar antenna and/or impedance matching of the antenna; and control means (230), responsive to the detecting means, for controlling the operation of the matching circuit (210), the weighting circuit (240) and the switch means (310) to adjust the properties of the multifilar antenna (200) to suit better a current signal to be received or transmitted.

Figure 2

Fig.1.

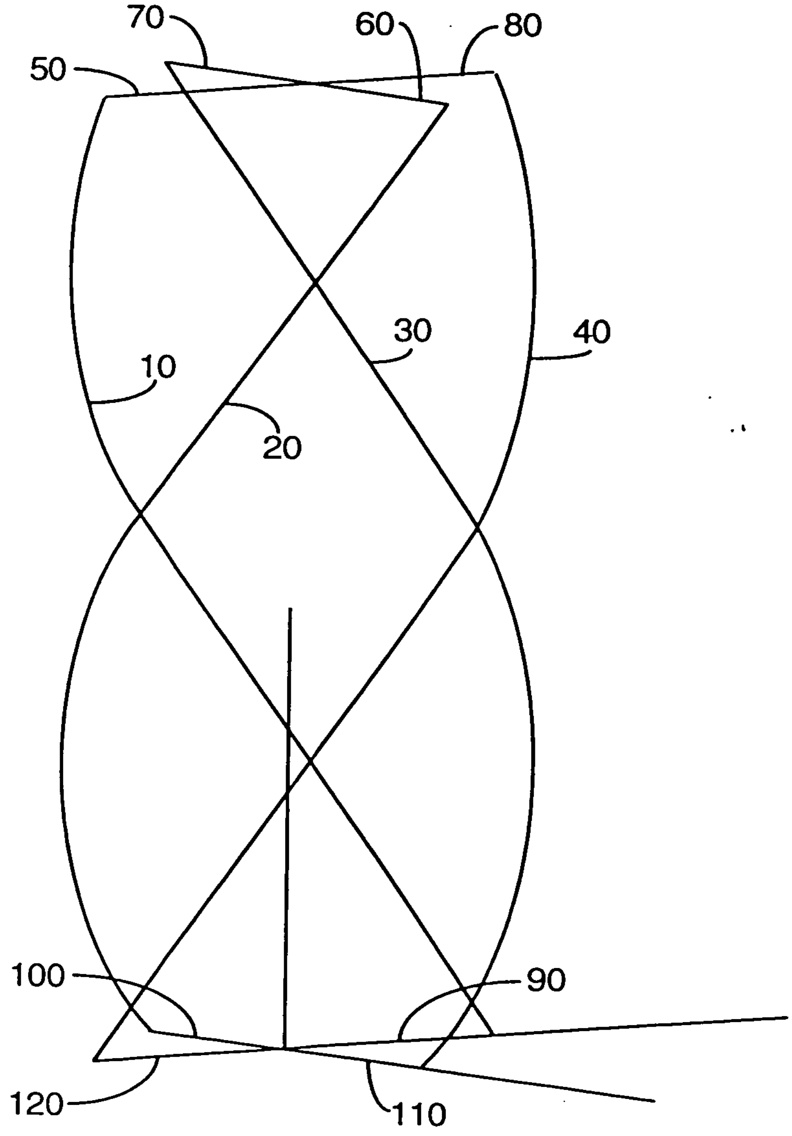


Fig.2.

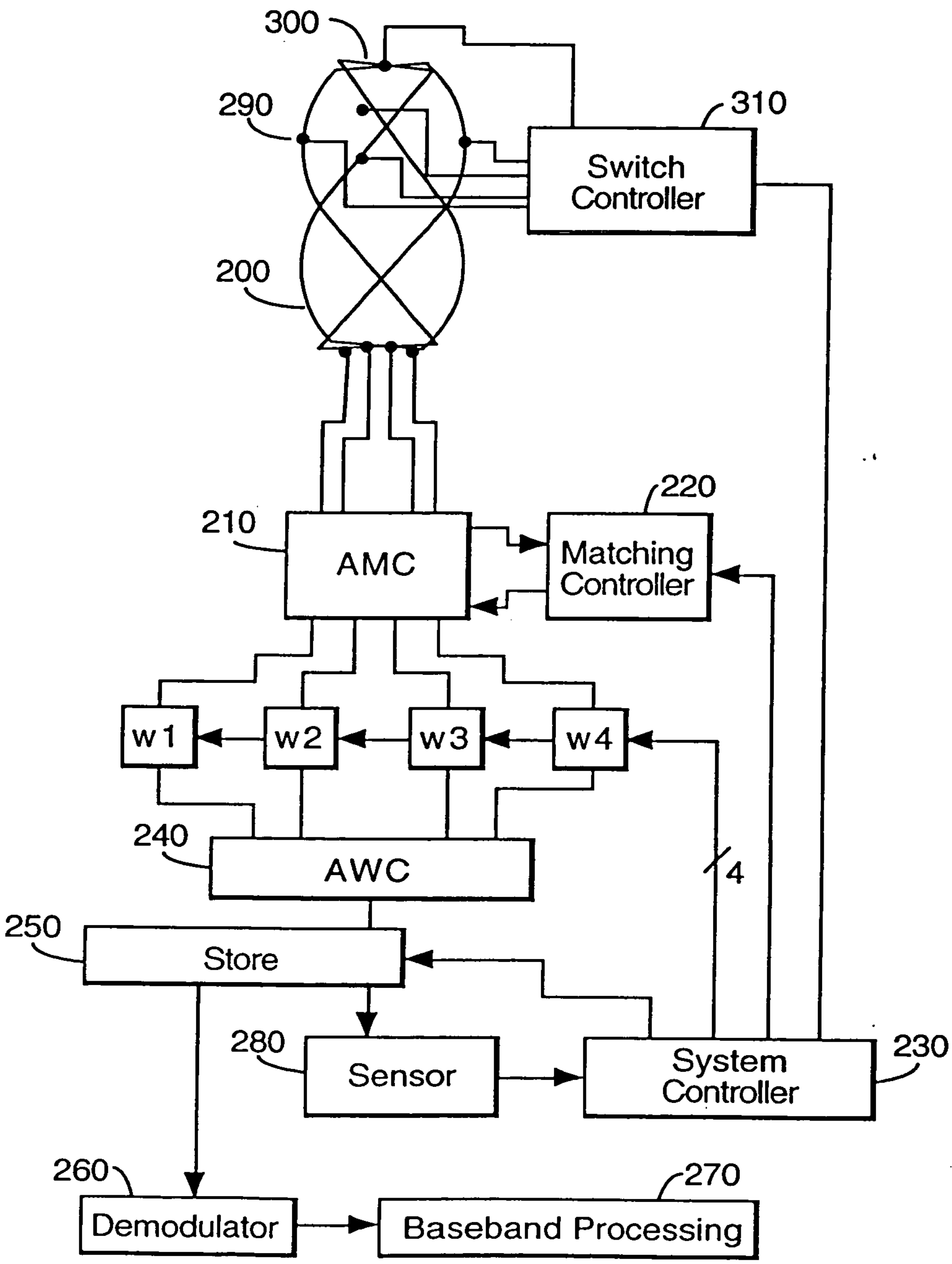
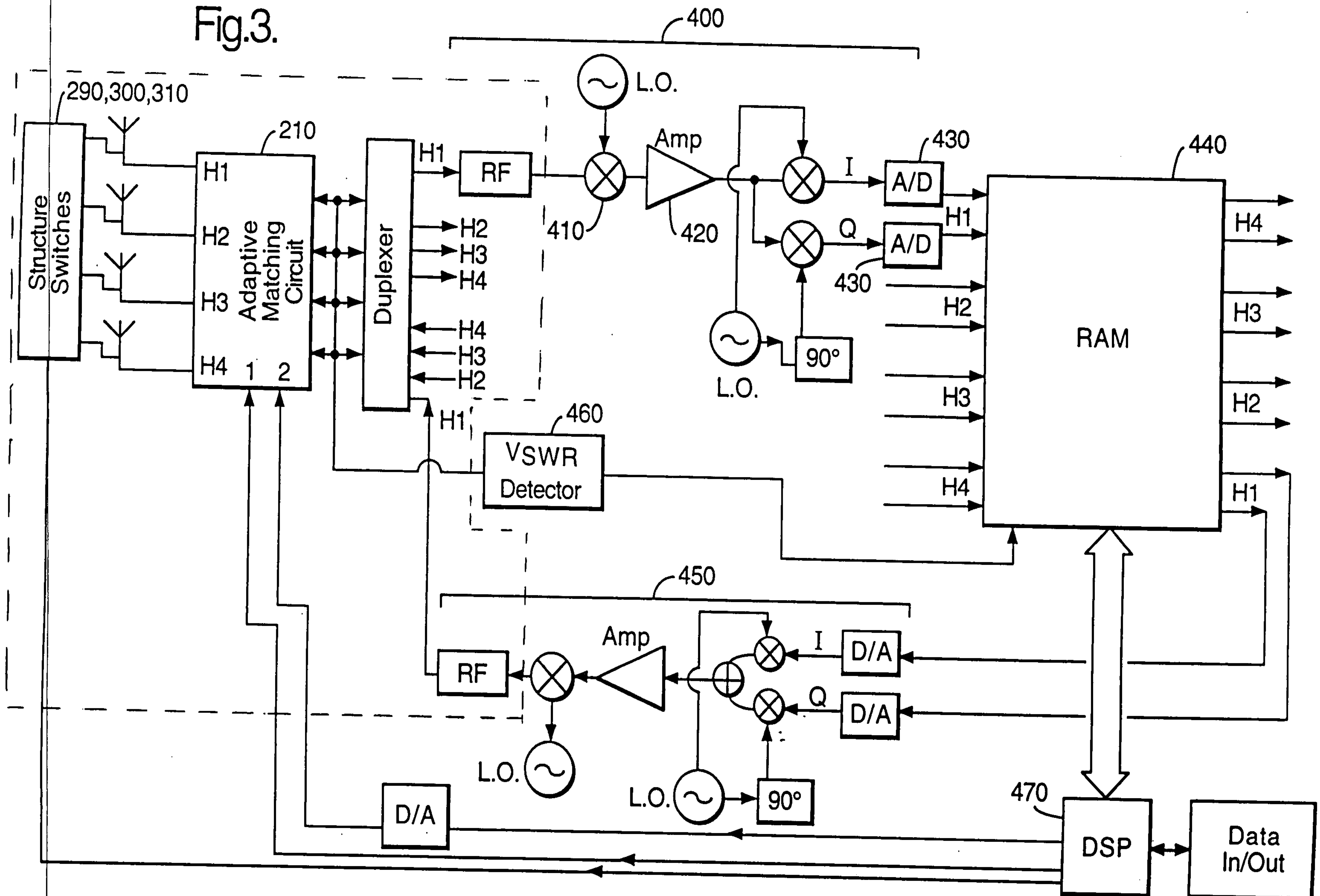
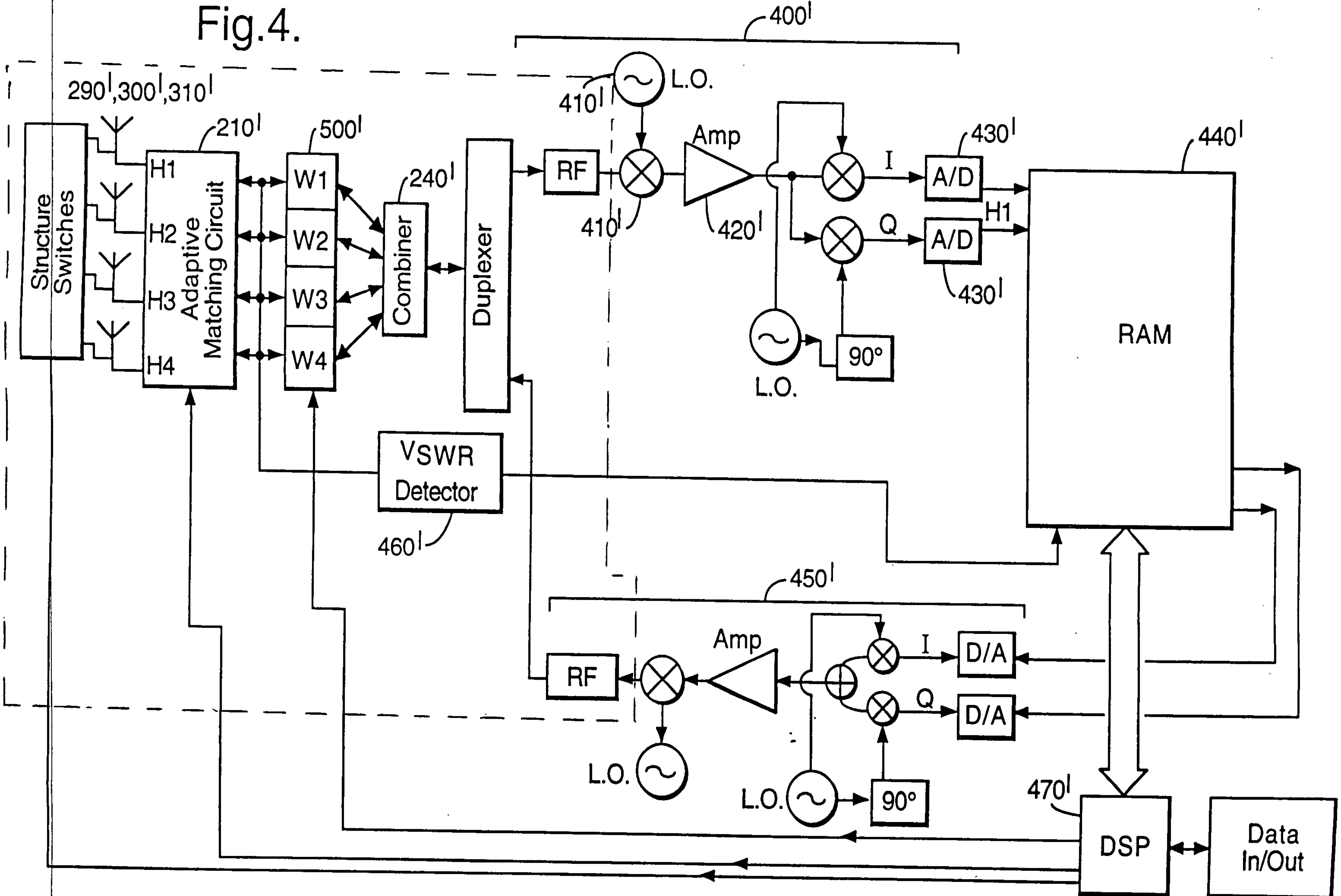

300
290
200
310
Switch Controller
210
AMC
220
Matching Controller
w1
w2
w3
w4
240
AWC
4
250
Store
280
Sensor
System Controller
230
260
Demodulator
270
Baseband Processing

Fig.3.


400
L.O.
290,300,310
210
Structure Switches
Adaptive Matching Circuit
H1
H2
H3
H4
1
2
Duplexer
RF
410
Amp
420
I
Q
430
A/D
440
RAM
90°
L.O.
460
VSWR Detector
450
Amp
D/A
470
DSP
Data In/Out

4/6

Fig.4.



Structure Switches
290',300',310'
210'
H1
H2
H3
H4
Adaptive Matching Circuit
500'
W1
W2
W3
W4
240'
Combiner
Duplexer
VSWR Detector
460'
400'
RF
410'
410'
L.O.
Amp
420'
I
Q
L.O.
90°
430'
A/D
A/D
430'
H1
440'
RAM
450'
RF
L.O.
Amp
I
Q
D/A
D/A
L.O.
90°
470'
DSP
Data In/Out

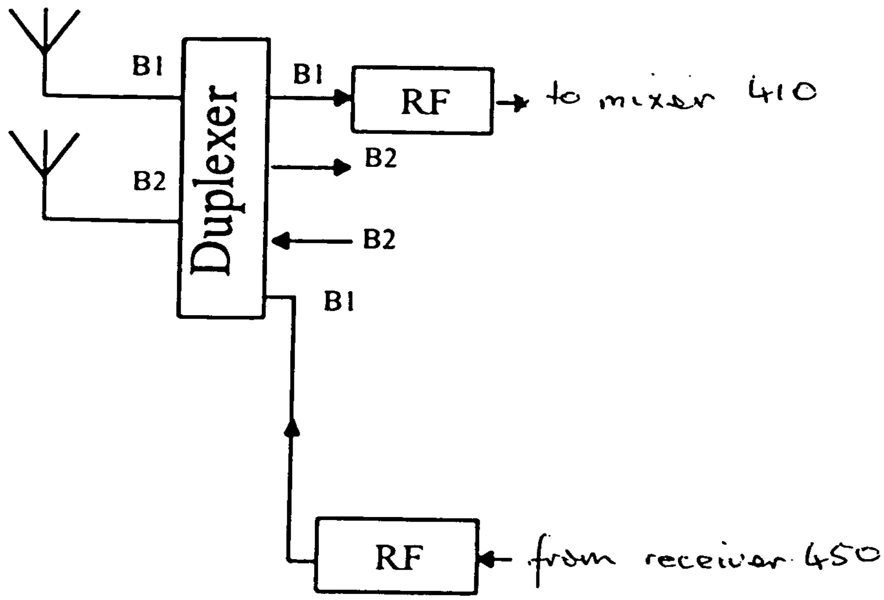

B1
B2
Duplexer
B1
RF
to mixer 410
B2
B2
B1
RF
from receiver 450

Fig. 5

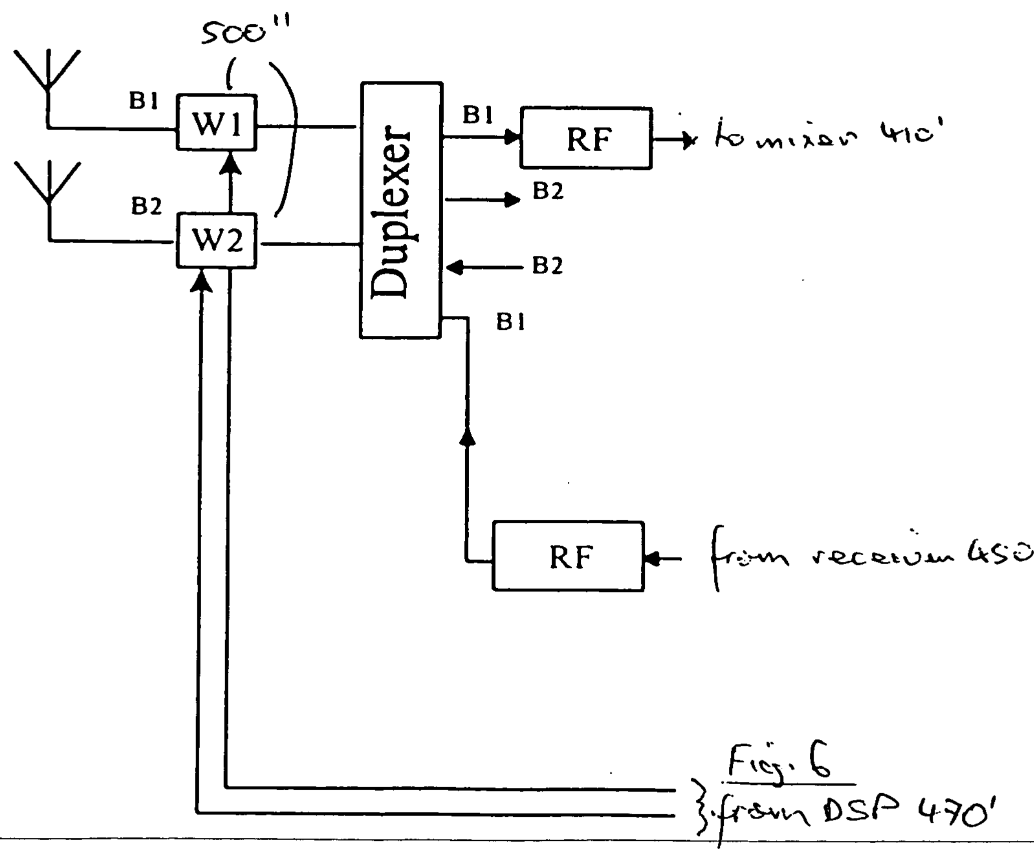
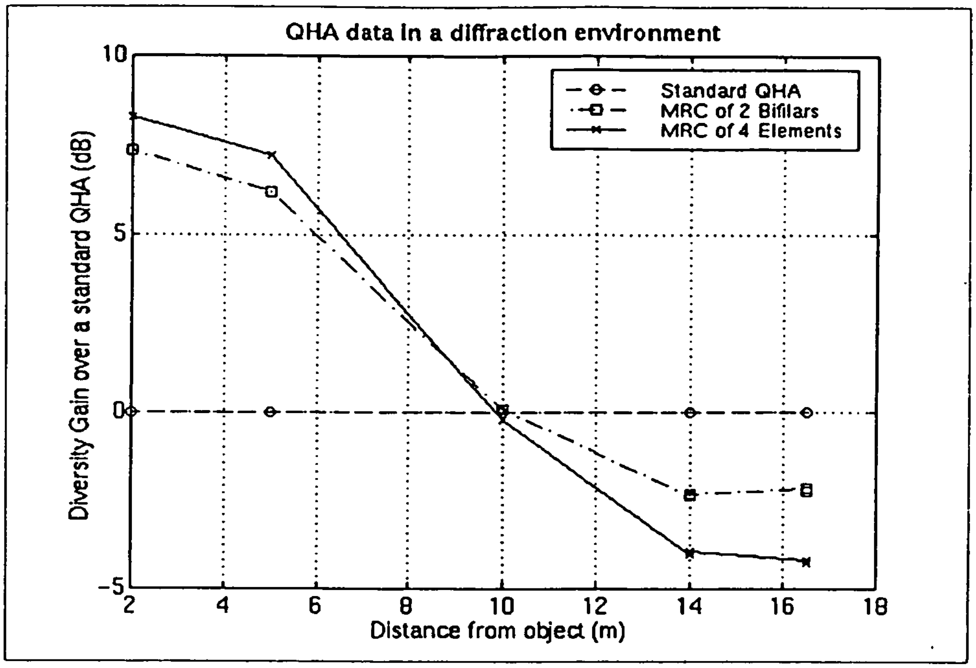

500''
B1
W1
B2
W2
Duplexer
B1
RF
to mixer 410'
B2
B2
B1
RF
from receiver 450'
from DSP 470'

Fig. 6



QHA data in a diffraction environment
Standard QHA
MRC of 2 Bifilars
MRC of 4 Elements
Diversity Gain over a standard QHA (dB)
Distance from object (m)
10
5
0
-5
2
4
6
8
10
12
14
16
18

Fig. 7

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